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Controlling the Length of Self-assembled Cu-Si Nanowires by Electric Field

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Self assembled metal silicide nanowires are considered prospective basic building blocks for future nanoscale devices [1]. A self assembly method, which is a bottom-up approach, generally can produce a large volume of nanowires in a short amount of time with relatively simple procedures. Hence, self assembly methods are very attractive especially in a large scale operation. As compared to top down methods such as the electron-beam lithography, fabrication of a nanowire can take up to several hours. Although, there are many self assembly methods, our focus is on electron-beam evaporation of copper (Cu) on thermally heated silicon (Si) in ultrahigh vacuum (UHV) [2], which directly self assemble planar copper-silicide (Cu-Si) nanowires on the substrate. As with most self-assembly methods, despite having many benefits, the e-beam evaporation method has several drawbacks. One of the main issues is the inability to directly control the fabrication process, which results in self-assembled Cu-Si nanowires of varying shapes, diameters, and lengths. Wide variations in geometries and sizes are not practical for a large-scale production because manufacturers cannot produce repeatable nanoscale devices. Therefore, our aim of this study is to control one aspect of the fabrication process, which is the length of the self assembled Cu-Si nanowires. Roos et al. in [3] proposed that the growth mechanics of self assembled silver (Ag) nanowires on Si(001) is by step bunching method. Since Cu-Si can self assembled into nanowires on Si(001) using the same approach as Roos et al., we assume Cu-Si nanowires also step bunch along vicinal Si. Therefore, we hypothesize that if the Si vicinal steps are long and straight, then the self assembled Cu-Si nanowires will be long and straight as well. Several studies such as in Refs. [4-6] have indicated that Si atoms under an electric field can electromigrate on the Si wafer surface, which then can transform the length of vicinal steps. In our experiments, we used only Si(110) substrates because there is only one Si<110> direction on the substrate surface. Since Cu-Si tend to self assemble along Si<110> direction [7], the fabricated nanowires will only be along a single direction. Hence, by changing the direction of the electric field on Si(110) during the e-beam evaporation process, the length of the self assembled Cu-Si nanowires can be observed and verified. The results strongly suggest that, on average, self-assembled Cu-Si nanowires will be the longest when the electric field is perpendicular to Si<110> and shortest when the electric field is parallel to Si<110>. Therefore, our experiments have shown that self-assembled Cu-Si nanowires can be controlled by the electric field.

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